PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: John I. Lipp	Group Art Unit: 2124
Serial No.: 10/023,346	Examiner: TAN V. MAI
Filed: 12/17/2001	Atty. Dkt. No.: 2063.001700
For: Kalman Filter With Adaptive Measurement Variance Estimator	Client Docket: VS-00533

APPEAL BRIEF

Customer No.: 23720

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Sir:

Applicant hereby submits this Appeal Brief to the Board of Patent Appeals and Interferences in response to the Advisory Action dated November 1, 2005. A request for a two month extension of time to respond is included herewith. The extension fee is included in the attached check. This two month extension will bring the due date to May 11, 2006. Should such request or fee be deficient or absent, consider this paragraph such a request and authorization to withdraw the appropriate fee. The fee for filing this Appeal Brief is $500.00 and is attached hereto. The Director is authorized to deduct or credit any additional fees to Williams, Morgan & Amerson, P.C. Deposit Account No. 50-0786/2063.001700.

I. REAL PARTY IN INTEREST

The present application is owned by Lockheed Martin Corporation.

II. RELATED APPEALS AND INTERFERENCES

Applicants, Applicants' representative(s), and the Assignee are not aware of any appeals, interferences, or judicial proceedings that are related to, may be affected by, might affect. or have a bearing on the Board's decision in this appeal.

III. STATUS OF THE CLAIMS

Claims 1-35 are pending in the case. The "final" Office Action rejected claims 1-6, 11-12, 17-18, 20, 22, and 24-35, but indicated that claims 7-10, 13-16, 19, 21 and 23 would be allowable but for their dependence from rejected base claims. Claims 1-6, 11-12, 17-18, 20, 22, and 24-35 were rejected as anticipated under 35 U.S.C. 102 (a) by Applicant's description of related art at pp. 2-4 of the application as filed.

IV. STATUS OF AMENDMENTS

Amendments to the claims were submitted in response to the "final" Office Action and were entered by the Office. These amendments are reflected in the listing of claims in the "CLAIMS APPENDIX".

V. SUMMARY OF CLAIMED SUBJECT MATTER

The invention is a Kalman filter with an adaptive measurement variance estimator.

Discrete Kalman filtering is extensively used in modern day digital control and signal processing for a variety of purposes. Among these purposes are to: "smooth" signals, *i.e.*, reduce measurement noise; observe unmeasured states; and/or predict future system states. In a typical discrete Kalman filter, all of the system parameters are specified. One of these system parameters is the "measurement covariance function matrix." The measurement covariance function matrix is frequently unknown. In these cases, an *ad hoc* value for the measurement covariance function matrix is used. Although this estimate is better than nothing, it nevertheless impairs the performance of the Kalman filter in its intended function, *i.e.*, smoothing, observing, and/or predicting. The present invention provides an improved measurement variance estimator.

Turning now to the drawings, **FIG. 1** conceptually illustrates a filtering mechanism 100 in accordance with the present invention. **FIG. 1** is reproduced below for the convenience of the Board. The filtering mechanism 100 includes a Kalman filter 110 and a variance estimator 120. One particular implementation for the variance estimator 120 is conceptually illustrated in **FIG. 2A**. A second, alternative particular implementation is shown in **FIG. 2B**. Both **FIG. 2A** and **FIG. 2B** are reproduced below, as well. Note the time delay τ in both **FIG. 2A** and **FIG. 2B**. Both these alternative embodiments are discussed further below. In accordance with the notation of Table 1 in the specification, for the nth sampling of the associated quantities:

$u[n] \equiv$ the input to the system;

$z[n] \equiv$ the measured output of the system;

$x[n] \equiv$ the current state of the system;

$K[n] \equiv$ the gain of the Kalman filter 110; and

$R[n] \equiv$ the variance of the input, or the measured output, or both, depending on the embodiment.

The "$\wedge$" notation indicates an estimate for a given quantity. Thus, $\hat{R}[n]$ and $\hat{x}[n]$ are estimates of the variance of the input $R[n]$ and the state of the system $x[n]$, respectively.

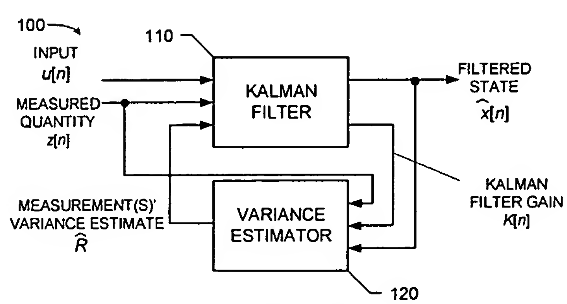

FIG. 1

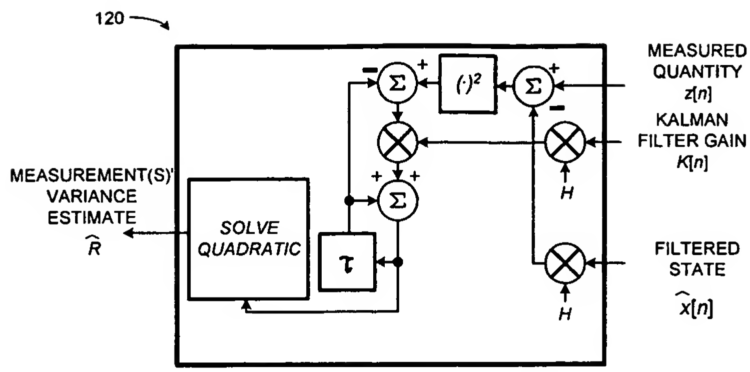

FIG. 2A

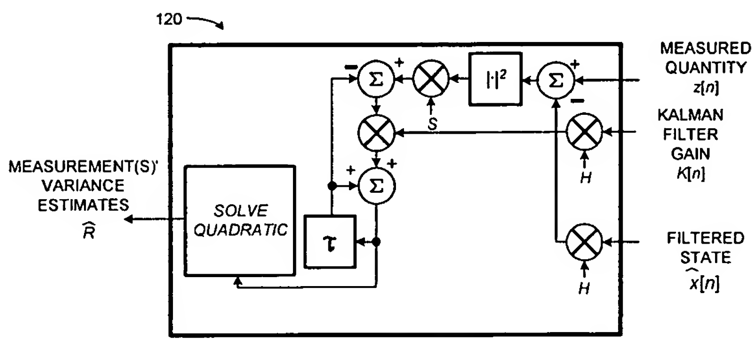

FIG. 2B

The present invention employs the same starting point as does the known filtering technique discussed in the "Background of the Invention" section of the specification. The measurements $z[n]$ and input $u[n]$ are Kalman filtered via the sequence of equations Eq. (13) – Eq. (17) set forth in the specification to arrive at an estimate $\hat{x}[n]$ of the true state $x[n]$. However, the variance estimation of the measured quantity signal $z[n]$ is performed differently than in the known technique. The estimation of $R[n]$ is accomplished by filtering the squared instantaneous prediction error $e^2[n]$, *e.g.*, with equations Eq. (18) – Eq. (31).

Thus, with respect to claim 1, a signal filtering mechanism (100, **FIG. 1**; p. 6, line 25 to p. 7, line 7), the invention comprises:

a Kalman filter (110, **FIG. 1**; p. 6, line 25 to p. 7, line 7) capable of receiving an input signal ($u[n]$, **FIG. 1**), a measured quantity signal ($z[n]$, **FIG. 1**), and a variance

estimate signal ($\hat{R}$, **FIG. 1**) for the measured quantity signal ($z[n]$, **FIG. 1**), and outputting a state estimate signal ($\hat{x}[n]$, **FIG. 1**); and

a variance estimator (120, **FIG. 1**; p. 6, line 25 to p. 7, line 7) capable of estimating the variance of the measured quantity signal ($z[n]$, **FIG. 1**) and generating the variance estimate signal ($\hat{R}$, **FIG. 1**) for use in filtering the input signal ($u[n]$, **FIG. 1**) and the measured quantity signal ($z[n]$, **FIG. 1**), wherein estimating the variance of the measured quantity signal ($z[n]$, **FIG. 1**) includes determining a smoothed estimate of the measured quantity's final variance from the measured quantity signal ($z[n]$, **FIG. 1**).

With respect to claim 4, a method for estimating the variance ($\hat{R}$, **FIG. 1**) of a measured quantity ($z[n]$, **FIG. 1**) used to predict the current state ($\hat{x}[n]$, **FIG. 1**) of a discrete, vector-state, scalar-measurement system, the invention comprises:

estimating (at 405, **FIG. 4**; p. 11, lines 19-29) the variance ($\hat{R}$, **FIG. 1**) of a measured quantity ($z[n]$, **FIG. 1**) for use in filtering an input quantity ($u[n]$, **FIG. 1**) and the measured quantity ($z[n]$, **FIG. 1**);

determining (at 410, **FIG. 4**; p. 11, lines 19-29) a smoothed estimate of an instantaneous prediction error's variance; and

filtering (at 415, **FIG. 4**; p. 11, lines 19-29) the input quantity ($u[n]$, **FIG. 1**) and the measured quantity ($z[n]$, **FIG. 1**) through a Kalman filter (110, **FIG. 1**) using the estimated input variance ($\hat{R}$, **FIG. 1**) of the measured quantity signal ($z[n]$, **FIG. 1**).

Independent claims 30 and 33 are program storage medium (515, **FIG. 5**; 550, **FIG. 5**; p. 12, line 12 to p. 13, line 11) and programmed computer (500, **FIG. 5**; p. 12, line 12 to p. 13, line 11) counterparts, respectively, of claim 4.

With respect to claim 17, a method (p. 16, line 19 to p. 17, line 9) for estimating the current state of a discrete, vector-state, scalar-measurement system, the invention comprises:

determining (at 805, **FIG. 8**; p. 16, line 19 to p. 17, line 9) a current state vector prediction from a previous state vector estimate and an input vector;

determining (at 810, **FIG. 8**; p. 16, line 19 to p. 17, line 9) a current state vector prediction covariance matrix associated with the current state vector prediction from a previous state vector covariance matrix associated with the previous state vector estimate;

estimating (at 815, **FIG. 8**; p. 16, line 19 to p. 17, line 9) the variance ($\hat{R}$, **FIG. 1**) of a measured quantity ($z[n]$, **FIG. 1**), wherein estimating the variance ($\hat{R}$, **FIG. 1**) includes:

determining a squared instantaneous prediction error of the measured quantity ($z[n]$, **FIG. 1**) from the measured quantity ($z[n]$, **FIG. 1**) and one of the current state vector estimate and the previous state vector estimate;

smoothing the squared instantaneous prediction error; and

estimating the final variance ($\hat{R}$, **FIG. 1**) of the measured quantity ($z[n]$, **FIG. 1**) from the smoothed squared instantaneous prediction error;

determining (at 820, **FIG. 8**; p. 16, line 19 to p. 17, line 9) a current Kalman filter (110, **FIG. 1**) gain vector from the current state vector prediction covariance matrix and the measured quantity variance estimate ($\hat{R}$, **FIG. 1**);

determining (at 825, **FIG. 8**; p. 16, line 19 to p. 17, line 9) a current state vector estimate from the Kalman filter (110, **FIG. 1**) gain, the current state vector prediction, and the measured quantity ($z[n]$, **FIG. 1**);

determining (at 830, **FIG. 8**; p. 16, line 19 to p. 17, line 9) the current state vector covariance matrix associated with the current state vector estimate from the Kalman filter (110, **FIG. 1**) gain and the current state vector prediction covariance matrix; and

iterating (at 835, **FIG. 8**; p. 16, line 19 to p. 17, line 9) the above.

With respect to claim 24, a signal filtering mechanism (100, **FIG. 1**; p. 6, line 25 to p. 7, line 7), the invention comprises:

means (at 110, **FIG. 1**; p. 6, line 25 to p. 7, line 7) for receiving an input signal ($u[n]$, **FIG. 1**), a measured quantity signal ($z[n]$, **FIG. 1**), and a variance estimate signal

($\hat{R}$, **FIG. 1**) for the measured quantity signal ($z[n]$, **FIG. 1**), and outputting a state estimate signal ($\hat{x}[n]$, **FIG. 1**); and

means (at 120, **FIG. 1**; p. 6, line 25 to p. 7, line 7) for estimating the variance ($\hat{R}$, **FIG. 1**) of the measured quantity signal ($z[n]$, **FIG. 1**) and generating the variance estimate signal ($\hat{R}$, **FIG. 1**) for use in filtering the input signal ($u[n]$, **FIG. 1**) and the measured quantity signal ($z[n]$, **FIG. 1**), wherein estimating the variance ($\hat{R}$, **FIG. 1**) of the measured quantity signal ($z[n]$, **FIG. 1**) includes determining a smoothed estimate of the measured quantity's final variance ($\hat{R}$, **FIG. 1**) from the measured quantity signal ($z[n]$, **FIG. 1**).

The "means" themselves are software that perform the function in the illustrated embodiment, or could be hardware in some implementations.

With respect to claim 27, an apparatus for estimating the variance ($\hat{R}$, **FIG. 1**) of a measured quantity ($z[n]$, **FIG. 1**) used to predict the current state of a discrete, vector-state, scalar-measurement system, the invention comprises:

means for estimating the variance ($\hat{R}$, **FIG. 1**) of a measured quantity ($z[n]$, **FIG. 1**) for use in filtering an input quantity ($u[n]$, **FIG. 1**) and the measured quantity ($z[n]$, **FIG. 1**);

means for determining a smoothed estimate of an instantaneous prediction error's final variance ($\hat{R}$, **FIG. 1**); and

means for filtering the input quantity ($u[n]$, **FIG. 1**) and the measured quantity ($z[n]$, **FIG. 1**) through a Kalman filter (110, **FIG. 1**) using the estimated input variance ($\hat{R}$, **FIG. 1**) of the measured quantity signal ($z[n]$, **FIG. 1**).

The "means" themselves are software that perform the function in the illustrated embodiment, or could be hardware in some implementations.

Note that references to the drawings and specification are to the illustrated embodiments as required by rule and are not limitations on the claims.

VI. GROUND OF REJECTION TO BE REVIEWED ON APPEAL

Whether claims 1-6, 11-12, 17-18, 20, 22, and 24-35 are anticipated under 35 U.S.C. 102 (a) by Applicant's description of related art at pp. 2-4 of the application as filed.

VII. ARGUMENT

Claims 1-6, 11-12, 17-18, 20, 22, and 24-35 were rejected as anticipated under 35 U.S.C. 102 (a) by Applicant's description of related art at pp. 2-4 of the application as filed. An anticipating reference, by definition, must disclose every limitation of the rejected claim in the same relationship to one another as set forth in the claim. M.P.E.P. § 2131; *In re Bond*, 15 U.S.P.Q.2d (BNA) 1566, 1567 (Fed. Cir. 1990).

More particularly, the Office maintains that equations (11) – (14) and (19) are the same as equations (1)-(4), and so the claims must be anticipated. However, the Office has admitted that Eq. (20) departs from Applicant's description of the related art. Eq. (7), on which the Office relies, is formulated as an estimate of the ***current*** variance. (p. 3, lines 22-27) Eq. (20) is, in contrast, formulated as an estimate of the ***final*** variance, that is, the variance as time approaches infinity. (*see* p. 11, lines 4-29) In response to the "final" Office Action, Applicant submitted amendments to amend to incorporate this distinction and the Office entered the amendments. More particularly, claims 1, 17, 24, 27, 30, and 33[1] were amended to recite "determining a smoothed estimate of the measured quantity's ***final*** variance from the measured quantity signal" (emphasis added) or some variant thereon.

Applicant therefore respectfully submits that each of claims 1, 17, 24, 27, 30, and 33 and their dependents include this limitation and are in condition for allowance. The Office nevertheless maintained the rejections in the Advisory Action, stating that:

> Although the Eqs. (7) and (20) are different, the specification does NOT states that they are CURRENT variance and FINAL variance as mentioned in the REMARKS. Therefore, the amended feature "Final" variance can read in either Eq. (7) or Eq. (20).

[1] It appears Applicant inadvertently omitted such an amendment to claim 4 and is therefore outside the scope of this argument.

Applicant is somewhat unsure exactly what the Office's position is, but notes that the Office entered the amendments, which is an implied concession that the limitations do not present "new matter". Consequently, the Office has also conceded that the limitations are supported by the specification and drawings. Accordingly, the Office's actions directly contradict the apparent reasoning of this position.

However, even were this not true, this position is directly contradicted by the specification. The specification clearly describes Eq. (7) as "current":

> This technique can essentially be broken down into three parts. First, the current state is predicted (Eq. (3), Eq. (4)). ***Next, the variance of the measured quantity is estimated (Eq. (5), Eq. (6), and Eq. (7)). Then, the current state is updated*** with the measurement (Eq. (8), Eq. (9), Eq. (10)). This known technique's variance estimate $\hat{R}[n]$ is often quite large. Also, it is possible for the measurement variance estimate to be zero, which happens in practice, and causes all manner of problems.

(p. 3, lines 22-27, emphasis added) Thus, the term "final" ***cannot*** be read into Eq. (7).

It is true that Eq. (20) is not described using the adjective "final". However, it does not have to be. As noted above, the Office has impliedly conceded through its actions that Eq. (20) addresses the final variance. Furthermore, it is clear from the disclosure that variance of Eq. (20) is other than the "current" variance. In particular, the flowchart of Figure 3 and the accompanying text on p. 8, line 8 to p. 10, line 2. In particular, note the statement:

> Typically, a Kalman filter converges, or "stabilizes," after a dozen or so measurements. After this point, it is also expected that the smoothed, squared, instantaneous error $\hat{\sigma}_e^2[n]$ has converged to approximately $\sigma_e^2[\infty]$.

(p. 9, lines 23-25) Thus, it is clear that Eq. (20) represents a "final" variance estimate and cannot be construed as a "current" variance estimate.

Thus, claims 1, 17, 24, 27, 30, and 33 were amended to recite "determining a smoothed estimate of the measured quantity's ***final*** variance from the measured quantity signal" (emphasis added) or some variant thereon, which is not taught by the cited art. The cited art therefore does

not anticipate claims 1, 17, 24, 27, 30, and 33 and the claims depending therefrom. M.P.E.P. § 2131; *In re Bond*, 15 U.S.P.Q.2d (BNA) 1566, 1567 (Fed. Cir. 1990). Applicant therefore prays that the rejections be REVERSED and the claims allowed to issue.

VIII. CLAIMS APPENDIX

The claims that are the subject of the present appeal—claims 1-35—are set forth in the attached "Claims Appendix."

IX. EVIDENCE APPENDIX

There is no separate Evidence Appendix for this appeal.

X. RELATED PROCEEDINGS APPENDIX

There is no Related Proceedings Appendix for this appeal.

XI. CONCLUSION

Applicants therefore respectfully submit that the claims are allowable over the art of record. Accordingly, Applicants request that the rejections be REVERSED and the claims allowed to issue.

Please date stamp and return the enclosed postcard to evidence receipt of this document.

Respectfully submitted,

Date: May 11, 2006

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CLAIMS APPENDIX

(Claims in Issue)

1. (Previously Presented) A signal filtering mechanism, comprising:

a Kalman filter capable of receiving an input signal, a measured quantity signal, and a variance estimate signal for the measured quantity signal, and outputting a state estimate signal; and

a variance estimator capable of estimating the variance of the measured quantity signal and generating the variance estimate signal for use in filtering the input signal and the measured quantity signal, wherein estimating the variance of the measured quantity signal includes determining a smoothed estimate of the measured quantity's final variance from the measured quantity signal.

2. (Original) The signal filtering mechanism of claim 1, wherein determining the smoothed estimate comprises:

determining the squared instantaneous prediction error of the measured quantity signal;

smoothing the determined, squared instantaneous prediction error; and

estimating the measured quantity's variance from the smoothed squared instantaneous prediction error.

3. (Original) The signal filtering mechanism of claim 1, wherein determining the smoothed estimate comprises:

determining the absolute instantaneous prediction error in the measured quantity signal;

smoothing the determined, absolute instantaneous prediction error; and

estimating the measured quantity's variance from the smoothed absolute instantaneous prediction error.

4. (Original) A method for estimating the variance of a measured quantity used to predict the current state of a discrete, vector-state, scalar-measurement system, the method comprising:

estimating the variance of a measured quantity for use in filtering an input quantity and the measured quantity;

determining a smoothed estimate of an instantaneous prediction error's variance; and

filtering the input quantity and the measured quantity through a Kalman filter using the estimated input variance of the measured quantity signal.

5. (Original) The method of claim 4, wherein determining the smoothed estimate of the variance of the instantaneous prediction error of the measured quantity signal comprises:

determining the squared instantaneous prediction error in the measured quantity signal;

smoothing the determined, squared instantaneous prediction error; and

estimating the variance from the smoothed squared instantaneous prediction error.

6. (Original) The method of claim 5, further comprising initializing a plurality of quantities used in estimating the current state of the discrete, vector-state, scalar-measurement system.

7. (Original) The method of claim 6, wherein initializing the plurality of quantities includes:

setting the prediction of the initial state of the system to a first predetermined value; and

setting the initial prediction covariance matrix associated with the predicted initial state of the system to a second predetermined value; and

one of:

setting the error filter gain to a third predetermined value; or

setting the smoothed squared instantaneous prediction error to 0.

8. (Original) The method of claim 7, wherein the third predetermined value is a vector of ones.

9. (Original) The method of claim 7, wherein the error filter gain is set to a third predetermined value and filtering the input quantity and the measured quantity includes determining a Kalman filter gain vector, a current state vector estimate, and a state vector estimate covariance matrix after estimating the variance of the measured quantity.

10. (Original) The method of claim 7, wherein the smoothed squared instantaneous prediction error is set to 0 and filtering the input quantity and the measured quantity includes determining a Kalman filter gain vector, a current state vector estimate, and a state vector estimate covariance matrix before estimating the variance.

11. (Original) The method of claim 4, wherein determining the smoothed estimate of the variance of the instantaneous prediction error of the measured quantity signal comprises:

determining the absolute instantaneous prediction error in the measured quantity signal;

smoothing the determined, absolute instantaneous prediction error; and

estimating the variance from the smoothed absolute instantaneous prediction error.

12. (Original) The method of claim 11, further comprising initializing a plurality of quantities used in estimating the current state of the discrete, vector-state, scalar-measurement system.

13. (Original) The method of claim 12, wherein initializing the plurality of quantities includes:

setting the prediction of the initial state of the system to a first predetermined value; and

setting the initial prediction covariance matrix associated with the predicted initial state of the system to a second predetermined value; and

one of:

setting the error filter gain to a third predetermined value; or

setting the smoothed absolute instantaneous prediction error to 0.

14. (Original) The method of claim 13, wherein the third predetermined value is a vector of ones.

15. (Original) The method of claim 13, wherein the error filter gain is set to a third predetermined value and filtering the input quantity and the measured quantity includes determining a Kalman filter gain vector, a current state vector estimate, and a state vector estimate covariance matrix after estimating the variance of the measured quantity.

16. (Original) The method of claim 13, wherein the smoothed absolute instantaneous prediction error is set to 0 and filtering the input quantity and the measured quantity includes determining a Kalman filter gain vector, a current state vector estimate, and a state vector estimate covariance matrix before estimating the variance.

17. (Previously Presented) A method for estimating the current state of a discrete, vector-state, scalar-measurement system, the method comprising:

determining a current state vector prediction from a previous state vector estimate and an input vector;

determining a current state vector prediction covariance matrix associated with the current state vector prediction from a previous state vector covariance matrix associated with the previous state vector estimate;

estimating the variance of a measured quantity, wherein estimating the variance includes:

determining a squared instantaneous prediction error of the measured quantity from the measured quantity and one of the current state vector estimate and the previous state vector estimate;

smoothing the squared instantaneous prediction error; and

estimating the final variance of the measured quantity from the smoothed squared instantaneous prediction error;

determining a current Kalman filter gain vector from the current state vector prediction covariance matrix and the measured quantity variance estimate;

determining a current state vector estimate from the Kalman filter gain, the current state vector prediction, and the measured quantity;

determining the current state vector covariance matrix associated with the current state vector estimate from the Kalman filter gain and the current state vector prediction covariance matrix; and

iterating the above.

18. (Original) The method of claim 17, further comprising initializing a plurality of quantities used in estimating the current state of the discrete, vector-state, scalar-measurement system.

19. (Original) The method of claim 18, wherein initializing the plurality of quantities includes:

setting the value of the current state vector prediction to a first predetermined value;

setting the current state vector prediction covariance matrix to a second predetermined value; and

performing one of:

setting an error filter gain to a third predetermined value; or

setting the squared instantaneous prediction error to 0.

20. (Original) The method of claim 17, wherein the current state vector estimate, the current state vector prediction covariance matrix, and the current Kalman filter gain are updated after the variance of the measured quantity is estimated.

21. (Original) The method of claim 20, wherein, in estimating the variance of the measured quantity includes:

determining the squared instantaneous prediction error in the measured quantity includes applying the following analysis:

$$e^2[n] = \left(z[n] - H[n]\,\hat{x}[n \mid n-1]\right)^2;$$

smoothing the determined, squared instantaneous prediction error includes applying the following analysis:

$$\hat{\sigma}_e^2[n] = \hat{\sigma}_e^2[n-1] + H[n]\,G[n]\left(e^2[n] - \hat{\sigma}_e^2[n-1]\right);\text{ and}$$

estimating the variance of the measured quantity from the smoothed squared instantaneous prediction error comprises:

setting the estimated variance to a fourth predetermined value if the Kalman filter is not stable; or

applying the following analysis if the Kalman filter is stable:

determining the value of a[n] from:

$$a[n] = \frac{H[n]A[n]H[n]^T}{H[n]H[n]^T};$$

determining the value of q[n] from:

$$q[n] = \left(H[n]B[n]\right)Q[n](H[n]B[n])^T;\text{ and}$$

solving for $\hat{R}[n]$ from

$$\hat{R}[n]^2\left(2a^2[n]-1\right) + \hat{R}[n]\left[\hat{\sigma}_e^2[n]\left(1-3a^2[n]\right) - 2q[n]\right] + \hat{\sigma}_e^2[n]\left(q[n] + \hat{\sigma}_e^2[n]a^2[n]\right) = 0.$$

22. (Original) The method of claim 17, wherein the current state vector estimate, the current state vector prediction covariance matrix, and the current Kalman filter gain are updated before the variance of the measured quantity is estimated.

23. (Original) The method of claim 22, wherein, in estimating the variance of the measured quantity includes:

determining the squared instantaneous prediction error of the measured quantity includes applying the following analysis:

$$e^2[n] = \left(z[n] - H[n]\hat{x}[n]\right)^2;$$

smoothing the determined, squared instantaneous prediction error includes applying the following analysis:

$$\hat{\sigma}_e^2[n] = \hat{\sigma}_e^2[n-1] + H[n]\,G[n]\left(e^2[n] - \hat{\sigma}_e^2[n-1]\right);\text{ and}$$

estimating the variance from the smoothed squared instantaneous prediction error comprises:

setting the estimated variance to a fourth predetermined value if the Kalman filter is not stable; or

applying the following analysis if the Kalman filter is stable:

determining the value of $a[n]$ from:

$$a[n] = \frac{H[n]A[n]H[n]^T}{H[n]H[n]^T};$$

determining the value of q[n] from:

$$q[n] = \left(H[n]B[n]\right)Q[n]\left(H[n]B[n]\right)^T;\text{ and}$$

solving for $\hat{R}[n]$ from

$$\hat{R}[n]^4 \frac{a^2[n]}{\left(\hat{\sigma}_e^2[n]\right)^2} + \hat{R}[n]^3 \frac{1-3a^2[n]}{\hat{\sigma}_e^2[n]} + \hat{R}[n]^2\left(2a^2[n]-1\right)\left(1 - \frac{q[n]}{\hat{\sigma}_e^2[n]}\right) + \left(\hat{R}[n]3q[n] + q^2[n]\right)\left(a^2[n]-1\right) = 0.$$

24. (Original) A signal filtering mechanism, comprising:

means for receiving an input signal, a measured quantity signal, and a variance estimate signal for the measured quantity signal, and outputting a state estimate signal; and

means for estimating the variance of the measured quantity signal and generating the variance estimate signal for use in filtering the input signal and the measured

quantity signal, wherein estimating the variance of the measured quantity signal includes determining a smoothed estimate of the measured quantity's final variance from the measured quantity signal.

25. (Original) The signal filtering mechanism of claim 24, wherein determining the smoothed estimate comprises:

determining the squared instantaneous prediction error of the measured quantity signal;

smoothing the determined, squared instantaneous prediction error; and

estimating the measured quantity's variance from the smoothed squared instantaneous prediction error.

26. (Original) The signal filtering mechanism of claim 24, wherein determining the smoothed estimate comprises:

determining the absolute instantaneous prediction error in the measured quantity signal;

smoothing the determined, absolute instantaneous prediction error; and

estimating the measured quantity's variance from the smoothed absolute instantaneous prediction error.

27. (Previously Presented) A apparatus for estimating the variance of a measured quantity used to predict the current state of a discrete, vector-state, scalar-measurement system, the method comprising:

means for estimating the variance of a measured quantity for use in filtering an input quantity and the measured quantity;

means for determining a smoothed estimate of an instantaneous prediction error's final variance; and

means for filtering the input quantity and the measured quantity through a Kalman filter using the estimated input variance of the measured quantity signal.

28. (Original) The apparatus of claim 27, wherein the means for determining the smoothed estimate of the variance of the instantaneous prediction error of the measured quantity signal comprises:

means for determining the squared instantaneous prediction error in the measured quantity signal;

means for smoothing the determined, squared instantaneous prediction error; and

means for estimating the variance from the smoothed squared instantaneous prediction error.

29. (Original) The apparatus of claim 27, wherein the means for determining the smoothed estimate of the variance of the instantaneous prediction error of the measured quantity signal comprises:

means for determining the absolute instantaneous prediction error in the measured quantity signal;

means for smoothing the determined, absolute instantaneous prediction error; and

means for estimating the variance from the smoothed absolute instantaneous prediction error.

30. (Previously Presented) A program storage medium encoded with instructions that, when executed by a computing apparatus, perform a method for estimating the variance of a measured quantity used to predict the current state of a discrete, vector-state, scalar-measurement system, the method comprising:

estimating the variance of a measured quantity for use in filtering an input quantity and the measured quantity;

determining a smoothed estimate of an instantaneous prediction error's final variance; and

filtering the input quantity and the measured quantity through a Kalman filter using the estimated input variance of the measured quantity signal.

31. (Previously Presented) The program storage medium of claim 30, wherein determining the smoothed estimate of the variance of the instantaneous prediction error of the measured quantity signal in the encoded method comprises:

determining the squared instantaneous prediction error in the measured quantity signal;

smoothing the determined, squared instantaneous prediction error; and

estimating the final variance from the smoothed squared instantaneous prediction error.

32. (Previously Presented) The program storage medium of claim 30, wherein determining the smoothed estimate of the variance of the instantaneous prediction error of the measured quantity signal in the encoded method comprises:

determining the absolute instantaneous prediction error in the measured quantity signal;

smoothing the determined, absolute instantaneous prediction error; and

estimating the final variance from the smoothed absolute instantaneous prediction error.

33. (Previously Presented) A computing apparatus programmed to perform a method for estimating the variance of a measured quantity used to predict the current state of a discrete, vector-state, scalar-measurement system, the method comprising:

estimating the variance of a measured quantity for use in filtering an input quantity and the measured quantity;

determining a smoothed estimate of an instantaneous prediction error's final variance; and

filtering the input quantity and the measured quantity through a Kalman filter using the estimated input variance of the measured quantity signal.

34. (Original) The computing apparatus of claim 33, wherein determining the smoothed estimate of the variance of the instantaneous prediction error of the measured quantity signal in the programmed method comprises:

determining the squared instantaneous prediction error in the measured quantity signal;

smoothing the determined, squared instantaneous prediction error; and

estimating the variance from the smoothed squared instantaneous prediction error.

35. (Original) The computing apparatus of claim 33, wherein determining the smoothed estimate of the variance of the instantaneous prediction error of the measured quantity signal in the programmed method comprises:

determining the absolute instantaneous prediction error in the measured quantity signal;

smoothing the determined, absolute instantaneous prediction error; and

estimating the variance from the smoothed absolute instantaneous prediction error.